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THE SHAD*

Alosa sapidissima

As a table delicacy, the shad is one of the best known and most highly prized of the fishes of the Atlantic Coast of the United States. The flesh, although not oily, is particularly rich in flavor. The roe is a great favorite among connoisseurs of fine foods.

The shad belongs to a large group of economically important fishes, the clupeoids. Included in this group are several species such as sardines, the menhaden, and the river herring. The shad is a rather large, silvery fish having, along the back, greenish blue coloring with metallic luster and, at the shoulder, a dark spot, occasionally followed by several smaller spots.

Shad may be distinguished from the river herrings with which they are frequently associated in fresh water, by the shape of the maxillary, or upper jaw, which is long, slender, and nearly straight. The maxillary of shad extends to a point below the pupil of the eye while the maxillary of the river herrings extends only to the forward margin of the eye itself. In herring it is deep, somewhat curved and sharply indented in front. The glut herring may be distinguished easily by the black lining of its body cavity or peritoneum. The peritoneum of the shad is white.

The natural habitat of shad is restricted to the Atlantic Coast of North America, from Nova Scotia to Florida, where they occur in most of the principal rivers from the St. Lawrence River, Canada, to the St. John's River, Florida, but the center of distribution is in the region of the Delaware River and Chesapeake Bay.

The shad, a non-native species of the Pacific coast, was transplanted from the Atlantic coast in 1871 when 12,000 fry hatched from eggs taken from the Hudson River (N.Y.) were planted in the Sacramento River (Calif.). Other plants were made over several of the following years. The first run of mature shad entered the river in 1877 and by 1886 a million mature shad were taken from the waters of California and sold in local markets. The species has distributed itself along nearly 3,000 miles of the Pacific coast from central California to the Columbia River.

The maximum weight attained by shad on the Atlantic coast is 15 pounds, but fish weighing more than 9 pounds are extremely rare. In Chesapeake Bay the average weight is about 2½ pounds for males and 3½ pounds for females. In

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most other rivers, except the St. John's River, Florida, they run larger. In the Hudson, for example, males average about 3-1/2 pounds and females about 5 pounds. In the Delaware the shad are slightly larger than in either the Chesapeake or the Hudson.

Biology of the shad. Shad, like salmon, are anadromous with a strongly developed homing instinct that is, spending the greater part of their lives in the ocean, but entering suitable streams to spawn. The spawning grounds are in the fresh water sections of the rivers. Eggs are deposited there during the spring after the water has warmed to 54°F. and until the temperature reaches about 70°F. The average number of eggs produced by a roe shad is 150,000.

The hatching period is ordinarily 6 to 10 days, depending on the temperature of the water. The newly hatched shad are less than half an inch long and are transparent. They are very active even when first hatched. A large yolk sac provides food for about a week, after which time they feed freely.

A study of shad eggs spawned naturally has shown that nearly all of them are fertilized, but that large numbers fail to hatch for reasons unknown, and many others are destroyed by silt and fungus growths or are eaten by eels and other enemies. Study of the survival rate of shad eggs in the Hudson River and in rivers of South Carolina and Georgia revealed only 2 fry for each hundred eggs in catches of sampling nets in these waters. The larvae of shad, for two or three weeks after hatching, have little resemblance to the adults. Their long, extremely slender bodies are scaleless and almost transparent. By the end of the first summer, the young shad have attained a length of 3 to 5 inches and the general appearance of the adult.

The migration of the young to salt water begins as soon as they reach the characteristic size of river growth, and may be as early as July, and continuing into late fall. At this time they migrate out of the rivers and do not usually reappear until they have reached sexual maturity several years later. On an average some of the males or "bucks" return when three or four years old, and females or "roes" come in a year or two later. So consistently do shad return to spawn in the rivers where they were hatched that a separate race of shad had grown up in each river.

It has been found also that the growth marks on scales, and a number of measurable racial characters from shad in one river differ significantly from those of had taken in other rivers.

The commercial fishery for shad is carried on during the spawning migration of fish into fresh water. The ocean habitat of shad is not well known. A few young shad are caught with schools of Menidia "white bait" during the winter along the shores of Long Island (N.Y.), small catches of adult shad have been made with herring off the coasts of Maine and Massachusetts and small quantities are often taken in otter trawls on the offshore banks. However, except for locations in the river estuaries or along the shores, large concentrations of shad are not usually found in salt water. One exception is a heavy concentration of shad that gathers in the fall near Mt. Desert Rock, 20 miles offshore from Mt. Desert Island, Maine, that is becoming the object of a growing fishery.

In any given stream successive schools of spawning fish appear over a period of several months, resulting in a rise and fall in the catch. Males predominate in the early runs, their numbers sometimes amounting to 90 percent of the total. After spawning, the spent fish begin their return to the sea. They are very weak and emaciated from lack of food and sometimes, if the weather is warm, many die along the way.

Adult shad are known to feed partly on mysid shrimps, amphipods, etc., when nearing the mouths of the rivers in the spring migrations, but their oceanic food is unknown.

Artificial propagation. Shad early received attention of the fish culturists and methods of artificial propagation were developed by 1867. The United States Fish Commission commenced hatching shad on the Connecticut River at South Hadley Falls, Massachusetts, in 1872, and later operated hatcheries on the Potomac, Delaware and Susquehanna Rivers. Hatcheries were also operated more or less intermittently by Maryland, Connecticut, New York, South Carolina, Virginia and Florida. More than a billion larvae were released from the hatcheries between 1880 and 1910, when some of the hatcheries were closed and operations of others were curtailed. Pond raising of shad before release has been carried on to only a limited extent.

Decline of Shad Runs. Although the early history of the shad fishery is not documented by records of annual production, the later phases are shown by published statistics of the annual catches. (Table I).

The earliest record of the total annual catch of shad is for 1880 when only 16,897,000 pounds were taken. The catch had increased by 1896 when the total catch of shad along the Atlantic seaboard amounted to 50,499,000 pounds. Production of shad then was surpassed only by the cod and the salmon of all the fishes of the United States.

At the same time that catches were increasing, the amount and effectiveness of the gear employed by the fisheries had increased in even greater proportion than the catches. Shortly after the 1900 the catches in all the rivers began to decline.

Since there is a separate race of shad indigenous to each river the rate of decline differs somewhat from river to river but there are features of similarity in the declines of many runs. Most striking was the sudden drop in production for all rivers between 1896 and 1908. The average drop for all rivers amounted to approximately 50 percent. As compared with the catch of 50,499,000 pounds in 1896 the total catch in 1908 was 25,936,000 pounds. The decline since 1908 has been more gradual but no less definite, for the catch totaled only 9,960,000 pounds in 1940, a decline of 80 percent from the peak production of 1896.

Exceptions to the general picture of decline are the Hudson River and, to a lesser extent, the Connecticut River. The catch in the Hudson has increased from an all-time low of 40,000 pounds in 1916 to between 3 and 5 million pounds annually in recent years. This recovery has been brought about and is being maintained by a moderate rate of fishing, which allows approximately 50 percent of each run to spawn.

As a result of this notable improvement, the catch in the Hudson River in 1944 was larger than that of the entire Chesapeake Bay area, normally the center of the Atlantic Coast shad fishery. Prior to 1908, the catch in the Chesapeake ranged from 10 to 17 million pounds annually. Since 1908 there has been a fluctuating decline to a level of about 2-1/2 million pounds in 1941.

Shad runs Can Be Increased. In view of the fact that regulation of fishing intensity has proved completely successful in restoring abundance in the Hudson, the Service recommends that chief reliance be place on proper management of the fishery, and that shad hatcheries operate on a salvage basis, utilizing eggs that would otherwise be wasted.

There were three main causes for the decline: overfishing, pollution and erection of dams. Overfishing was the most destructive of these causes because it was operative in all the rivers and bays over a long period of years. Pollution only became an important factor with the industrialization of sections adjacent to shad streams. Dams erected across rivers on or below the spawning grounds have reduced natural reproduction. Shad have refused to ascend fish ladders installed for them on the Atlantic Coast in existing dams. It is possible, however, that ladders of modern design might reopen spawning grounds long shut off by dams.

Complete restoration of the runs in the Hudson and the Connecticut rivers since 1934 has shown the way by which shad runs in many rivers can be restored. The restoration that was not accomplished for an shad fishery, earlier, by artificial propagation, has been achieved in the Hudson River, by fishing at a moderate instead of an excessive rate. Larger numbers of adults were allowed to spawn and the runs were built up through natural reproduction. In 1944 Hudson River fishermen took less than 40 percent of the run- estimated by scale studies and returns from tagged fish - yet they caught more pounds of shad than at any previous time when fishing rates were much higher.

In Chesepeake Bay, where production of the shad fishery has continued to decline, the fishing rate in 1939 was estimated at over 90 percent of the run. Due to manpower shortages since the war the fishing rate has been somewhat reduced. In 1941, Maryland adopted a management plan by which liscenses and gear are limited.

Runs in many southern rivers free of pollution and with no obstructions might also be restored by reduction of fishing rate.

Abatement of pollution will be necessary in some rivers and adequate fishways to provide passage over dams in most New England rivers and in the Susquehanna River before the shad runs can be restored to their early abundance.

Need for Scientific Research. Scientific research is important in the application of any fishery management program to the shad fishery. The most advantageous rates are still to be determined by experimentation, as are the amount and types of gear required to harvest the crop most economically. Other studies should be conducted to determine the oxygen requirements of shad and their range of tolerance for various chemical constituents of pollutants to guide

the agencies concerned with abatement of pollution in certain of the rivers. Increased production through planned conservation for greater use of this fishery resource will demand broader markets to absorb the supply without appreciable reduction in unit price to the fishermen.

Information on the shad may be found in the following publications:

Bigelow, Henry B. and Wm. W. Welsh
Fishes of the Gulf of Maine. Bureau of Fisheries Document No. 965; Bulletin U. S. Bureau of Fisheries, Vol. XL, Part 1, 1924, 567 pages. $2.00.

Hildebrand, S. F. and Wm. C. Schroeder.
Fishes of the Chesapeake Bay. Bureau of Fisheries Document No. 1024, Pt. 1, Vol. XLIII, 1927, Bulletin U. S. Bureau of Fisheries, 368 pp 211 illus. $1.50.

Leach, Glen C.
Artificial Propagation of the Shad. Bureau of Fisheries Document No. 981, Report of U. S. Commissioner of Fisheries for 1924, pp. 459-486, 10¢.

Leim, A. H.
The Life History of the Shad (Alosa sapidissima (Wilson), with special reference to the factors limiting its abundance. Contributions to Canadian Biology, being studies from the Biological Stations of Canada, N.S., Vol. II, part I, 1924, University of Toronto Press, 1924.

Smith, Hugh M.
The Fishes of North Carolina. 456 pp., 21 pls., 188 figs., Vol. II of North Carolina Geological and Economic Survey, Raleigh, N. C. (Out of print).

Stevenson, Charles H.
The shad fisheries of the Atlantic Coast of the United States, Report of the U. S. Commissioner of Fisheries for 1898, pp. 101-269. (1899). (Out of print).

U. S. Government publications may be consulted in many public libraries. Those which are not out of print may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. at the prices stated.

Table I

COMPARISON OF THE CATCH, IN POUNDS, OF SHAD

IN THE HUDSON RIVER AND CHESAPEAKE BAY FOR

VARIOUS YEARS SINCE 1896

Year	Chesapeake Bay	Hudson River
1896	16,712,000	2,201,000
1897	17,329,000	1,884,000
1901	10,083,000	3,432,000
1904	10,332,000	498,000
1908	11,251,000	360,000
1915	6,169,000	68,668
1916	No survey	40,173
1920	9,161,000	199,800
1923	8,040,000	121,700
1925	7,364,000	124,300
1928	No survey	246,200
1930	7,181,000	206,500
1931	8,487,000	414,600
1932	6,515,000	529,750
1933	6,191,000	518,680
1934	4,990,000	438,000
1935	3,683,000	847,000
1936	2,185,000	2,467,900
1937	3,491,000	2,730,600
1938	4,207,300	2,467,000
1940	3,256,500	2,114,300
1941	2,659,500	3,133,500
1944	No survey	5,000,618

Source: From reports of the Division of Commercial Fisheries, Fish and Wildlife Service.

Table 2

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DECLINE OF ATLANTIC COAST SHAD CATCH
EXPRESSED IN POUNDS

Year	New England	Middle Atlantic	Chesapeake Bay	South Atlantic	Total Atlantic Coast
1887	1,622,000	12,775,000	7,856,000	7,377,000	29,630,000
1890	1,344,000	19,095,000	14,394,000	9,432,000	44,265,000
1895	1,389,000	18,163,000	15,915,000	10,743,000	46,210,000
1897	1,407,000	18,513,000	17,329,000	11,268,000	48,517,000
1900	1,398,000	20,988,000	11,895,000	10,417,000	44,698,000
1905	1,261,000	6,174,000	10,562,000	9,211,000	27,208,000
1910	1,224,000	4,144,000	8,764,000	7,434,000	21,566,000
1915	1,066,000	2,437,000	6,169,000	4,594,000	14,266,000
1920	855,000	731,000	9,161,000	3,101,000	13,757,000
1925	473,000	839,000	7,364,000	3,148,000	11,824,000
1930	201,000	450,000	7,181,000	2,541,000	10,373,000
1935	727,000	1,329,000	3,683,000	2,497,000(1934)	8,236,000
1937	445,000	4,394,000	3,491,000	1,318,000	9,648,000
1938	503,000	3,591,000	4,208,000	1,418,000	9,720,000
1939	530,000	4,131,000	4,184,000	1,232,000	10,077,000
1940	574,000	4,746,000	3,257,000	1,342,000	9,960,000

Source: Annual Reports of the Division of Fishery Industries, U. S. Bureau of Fisheries.